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THE IRON CONCRETIONS OF THE REDBANK SANDS

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In the accompanying illustrations (Figs. 1–4), reproduced from photographs, are shown forms of iron concretions which seem to deserve notice alike for their peculiar structure, great length, uniform orientation, and effect on local topography.

These concretions are to be found in immense numbers in the Redbank sands of Monmouth County, New Jersey, a formation which is here a quite structureless bed of loose, rather fine quartzose sand about 100 feet thick, generally red in color from the decomposition of glauconite formerly disseminated through it. The concretions are most numerous near the upper part of the formation, and occur as isolated individuals imbedded in the sand, as well as more or less densely packed in groups.

The primary type of these concretions is a very long, more or less regular, hollow cylinder, which is generally straight and of unvarying diameter, but which sometimes tapers very gradually and may be of indefinite length. Single tubes have been observed which were more than 20 feet long, but it is impossible to remove unbroken such great lengths from the sand in which they are imbedded, owing to the occurrence of transverse cracks which divide them into irregular segments. Fig. 1 is from a photograph of such a segment; the diameter of the tube is 1½ inches. The smallest tube yet observed had a diameter of ¼ inch; the largest tube of *circular* cross-section so far seen had a diameter of nearly 1 foot. The interior of the cylinder is generally filled with sand differing in no respect from the sand without; the wall of the cylinder is merely the ordinary material of the sand-bed, cemented together by iron oxide. While the cross-section of the cylinder is often circular, more frequently it is quite irregular. Still more frequently the concretion is not a closed tube at all, but a corrugated sheet.

Besides simple tubes like that shown in Fig. 1, there are the polychambered types represented in Figs. 2 and 3. Fig. 2 has two unequal and somewhat dissimilar chambers. Fig. 3 shows an end view of a fragment of a three-chambered specimen. In Fig. 5 are shown cross-sections of a number of selected specimens. Fig. 6 is a sketch of the projecting ends of a group of concretions as they appeared in the bank of a railroad cut. Fig. 4 is from a photograph of a bluff in the Highlands of Navesink also showing projecting ends.

In the compound concretions there is usually one primary chamber which is more or less accurately circular in cross-section, and sometimes more than one. The cross-sections of the secondary or parasitic chambers are only arcs of circles. It is in fact a notable characteristic of all these concretions, of whatever dimensions or however otherwise irregular, that they show in cross-section practically no other lines than greater or smaller arcs of circles.

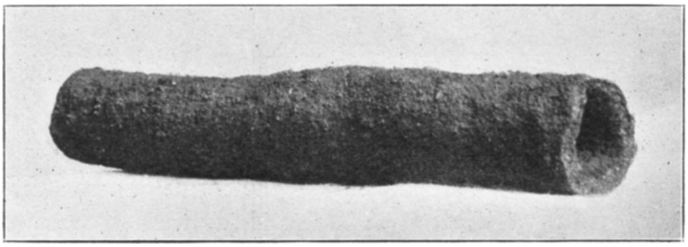

FIG. 1

As may be seen from Figs. 5 and 6, the number of secondary chambers in a single specimen may be large. Often in a compound individual the ratio of the dimensions of the primary and secondary chambers is rigidly maintained throughout its observed length, but this is not invariable. Frequently a secondary chamber will end abruptly in a *cul-de-sac;* just as frequently it will diminish gradually until its wall merges imperceptibly with the wall of its primary, so that a concretion which is compound at one end may dwindle down to a single primary tube at the other.

A noteworthy but puzzling feature is the fact that, without observed exception, these concretions all occupy a horizontal position, and lie with their longer axes parallel to the strike of the formation, which is

E. N. E., the dip being slight. In some exposures they are seen to occur in parallel zones which are considerably inclined to the normal dip of the strata in this region. As noted above, their distribution through the sand is, in general, irregular. In some large areas they appear to be totally absent, and occur but sparsely in others. In still other areas they are found in crowded aggregations containing an enormous number of individuals, all having the characteristic orientation. Where the concretions lie thickly crowded together, this common orientation gives them an appearance suggestive of great piles of cord-wood partially covered with sand. Such aggregations, which are often elongate in the same direction as the concretions themselves, are locally so numerous and large as to impress a peculiar stamp upon the topography, as they serve to protect the loose sand beneath from erosion; the resulting uniformly oriented hills of circumdenudation have somewhat the shape of drumlins. Such hills are numerous on the outcrop of the formation in the eastern part of Monmouth County.[1] The most interesting specimens are not usually found in these situations, as the abundance of iron has led to a thickening of walls and a running together of outlines. The best ones are to be obtained where the glauconite was sparingly disseminated, as in the large cut on the New York & Long Branch Railroad one mile west of Redbank. In this and many other localities the concretions may be dug out of the sand with no other implement than the bare hand; the interior filling may be removed by shaking, or with the aid of a straight stick.

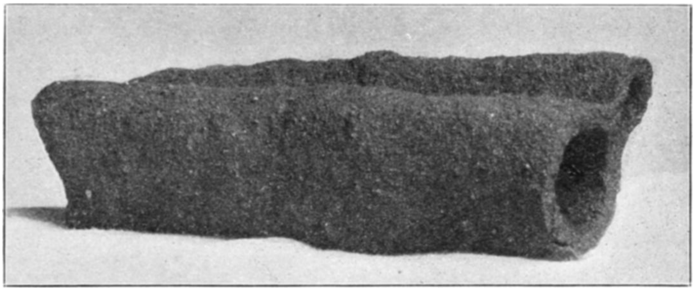

Fig. 2

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[1] See Sandy Hook Sheet, U. S. Geological Survey (topographic map) south of Eatontown and thence east to Long Branch.

If the removal of the interior filling be cautiously effected, best with the help of a gentle stream of water, there may sometimes be seen fragile, calcified, arborescent forms which ramify through the concretion in complete disregard of the interior partitions, and which are sometimes, but not often, preserved beyond the outer periphery. The dotted lines across two of the cross-sections in Fig. 5 indicate such arborescent forms. They are doubtless fossil stems of plants which were evidently present in the sand before the concretions were formed, and owe their preservation within the concretions to the exclusion of the underground circulation, which has no doubt in most cases removed by solution the parts not so inclosed. If this be the true interpretation, their presence is significant as showing that organic matter was formerly more abundant in the sand, yet they make it exceedingly difficult to believe that these concretions are fossilized remnants of elongate forms of animal or vegetable life, since it is inconceivable how such forms could have inclosed these calcified plants (if such they be) in the manner observed; besides, they bear no resemblance to any known form of life.

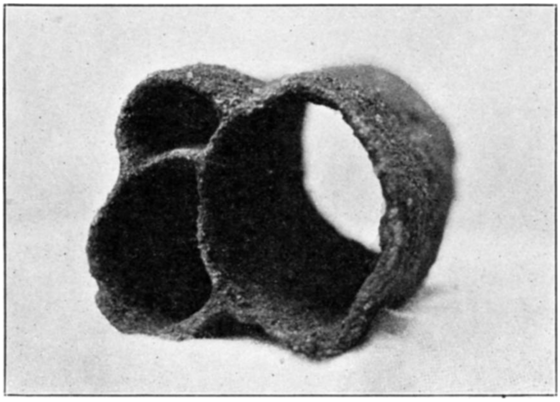

FIG. 3

Neither is there any reasonable probability that they have resulted from the filling of cracks and subsequent hardening of the filling material. In the first place, they are found in loose sand, which is certainly not a material in which to expect cracks of any kind; in the second place, the formation of long, straight, horizontal, tubular cracks, or such systems of cracks as would be necessary to give the observed forms to the compound concretions, would be a mechanical marvel under the most favorable circumstances. They are clearly not of stalactitic origin. The Redbank formation is ideally porous; where the concretions display their most typical characteristics the formation does not now, at any rate, possess any structural feature which may have served to guide convection currents. All the evidence obtainable seems to show that the material which supported the growth of the concretions was transported to them by diffusion rather than by convection. Transportation by diffusion here refers to movement of dissolved matter in obedience only to the molecular activities of the substance in solution, while transportation of the same by convection implies a bodily movement of the solution in a determinate direction. The distinction is important in this connection, since if water currents, along with other mechanical agencies, are denied any part in the formation of these objects, they must be regarded as an expression of a molecular tendency of the cementing material.

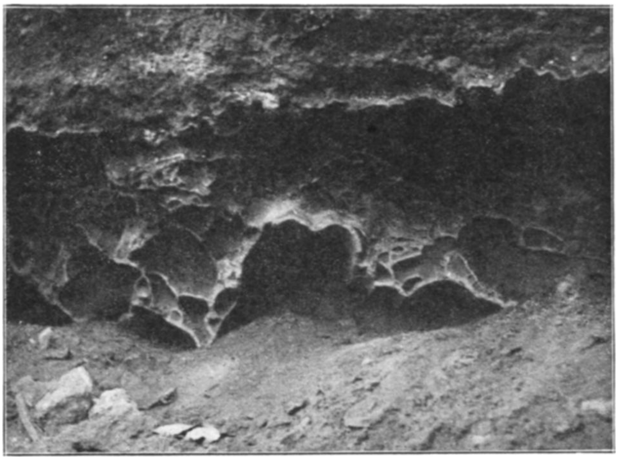

FIG. 4.—Bluff in the Navesink Highlands, showing irregular tubes and corrugated sheet.

The evidence in favor of transportation by diffusion is clear and positive. Where the concretions are absent the ferruginous coloring-matter is in general more or less evenly distributed through the sand; in the vicinity of the concretions the red color is much less pronounced, and may even disappear altogether, leaving the sand clean and white. This at least goes to show that the supply of cementing material was local. Further, many of the isolated concretions, compound as well as simple, lie in sheaths of pure white sand, which they have decolorized as decaying roots might have done. Fig. 7 illustrates a phenomenon often observed in the Redbank formation. There is here shown a segregation of the iron into more or less parallel bands, which locally give the sand a prominent but deceptive appearance of being finely stratified. However, the bands anastamose in a manner which shows that they are not the result of ordinary processes of bedding. The sand of the light bands is poorer, that of the dark bands richer, in iron than sand where segregation has not occurred. The iron oxide in the dark bands is sufficient in amount to occasion differential weathering, but real cementation has not yet taken place; the sand is still so loose that it may readily be excavated with the bare hand. These segregations probably represent a first concentration of the iron by the mutual attraction of like particles. In the sand-bank not far from where the photograph was taken is a large nest of concretions which have absorbed to themselves the iron of all the bands in their immediate vicinity.

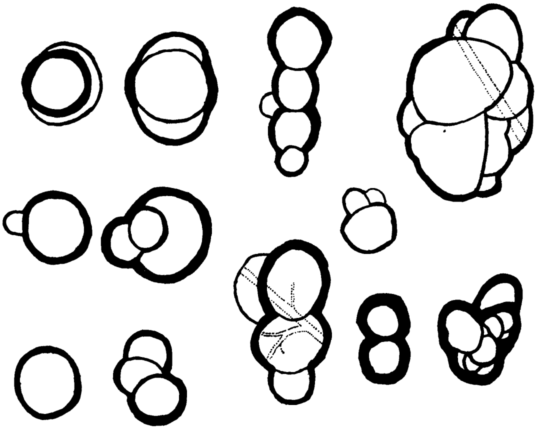

FIG. 5.—Cross-sections of selected concretions.

It is not maintained that convection currents have never circulated through the sand, but it is clear that they must have been quite subordinate when and where the concretions were actively forming.

Finally, a study of the interior structure of numerous compound concretions has shown relations for which the author confesses his inability to offer explanations based on hypotheses involving fortuitous mechanical circumstances, or possible modes of circulation of water containing the iron in solution. There is among all the phenomena associated with these concretions but one, in producing which mechanical influences can be suspected of having played a tangible part. This is the noteworthy parallelism of their longer axes with the strike of the formation, which suggests that shore currents or waves, acting parallel to or impinging upon the ancient Cretaceous shore, may have sorted into some definite arrangement the material the decomposition of which was later to furnish the cementing bond of the concretions. But the influence of waves or currents must have stopped with the action requisite to govern the orientation of the concretions, and could have played no further part in giving them their observed characteristics.

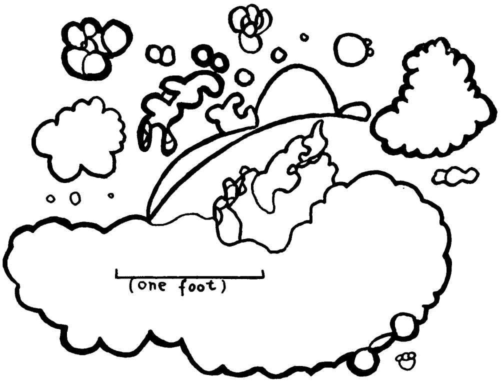

FIG. 6.—Sketch of the ends of a group of concretions seen in a railroad cut.

The author is therefore inclined to the hypothesis which regards these objects as forms proper to the cementing material, which will, under proper circumstances, be assumed in obedience to impulses residing in its molecules. There is evidence tending to show that these concretions have a fairly definite morphology. In many cases it is possible to show with great probability that the various tubes of the polychambered individuals were not synchronous in their origin. In Fig. 8 is given a generalized cross-section of a three-chambered concretion. The relations shown are thoroughly typical. It will be observed that only one—the largest—of the chambers, *A*, is really cylindrical in cross-section; the next largest, *B*, has the outline of a segment of a circle which is cut by the circle *A*; the smallest, *C*, has the outline of a segment of a circle cut by both *A* and *B*. From these relations, and from the relative thickness of the exterior walls and interior partitions, the history of the concretion is inferred to be somewhat as follows: The concretion probably consisted at first only of the tube *A;* in this condition it must have resembled the concretion shown in Fig. 1. As to what induced the formation of this tube, the concretion itself affords no direct evidence. It may be presumed that, once formed, the wall of the tube was thickened by addition of material chiefly from the outside, and that the rate of addition was practically the same at all points on the periphery. When the wall of *A* had attained the thickness represented by *a,* the arched chamber *B* barnacled itself on *A;* the arch *a,* thus cut off from outside supplies of material, suffered an arrest of growth. The concretion was now two-chambered, like the one shown in Fig. 2. By the time the exterior wall of *B* had attained the thickness of *b,* that of *A* had reached the thickness of *c.* A second parasitic chamber, *C,* was then arched across one of the sulci between *A* and *B; b* and *c* were thus cut off, and their further growth prevented while the exterior walls of the concretion, as it now appears, were taking on their present proportions. The existence of still more complex individuals, in which analogous relations between the several chambers and their walls obtain, shows that the process need not stop with the formation of a three-chambered concretion, but may be continued indefinitely. It is possible to col-

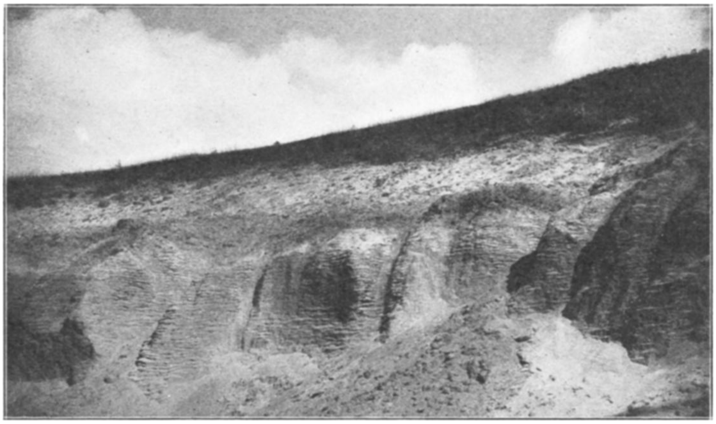

FIG. 7.—Sand bank in Long Branch, showing tendency of the iron (originally disseminated as glauconite) to segregate into anastamosing bands.

lect any number of suites of specimens having from one to a dozen chambers in which the order of the formation of the different arches may be made out with reasonable certainty. It will be observed that for each new chamber added to the concretion, a new curve is added to its outer boundary, so that in the more complex individuals this boundary becomes exceedingly tortuous.

The uni-chambered tubes of very large and very irregular cross-section, such as those shown in Fig. 6, are to be accounted for under two suppositions. The general appearance of their walls suggests that they were originally very complex individuals which had been built up in the regular way—i. e., by successive additions of secondary chambers—but which have lost their interior partitions through resolution. While this explanation of their origin has a certain plausibility, it is not regarded as the correct one. It is more likely that we have to recognize here the results of a process analogous to, if not identical with, the familiar "twinning" by which the different parts of a crystal may be oriented in contrary ways. If it be granted that the molecular tendencies residing in the cementing material be competent to cause it to assume the cylindrical form, it may be taken for granted that the cross-section of the young concretion will be an arc of a circle before it becomes a full circle. It is well-known that in the process of crystallization growing crystals are not always guaranteed against twinning; the molecular forces which govern crystallization are capricious. In the case of the young concretion there is no reason to suppose that the arc would always become a complete circle. From what is to be seen in numerous cross-sections, it appears that the centers and degrees of curvature were subject to change at frequent but irregular intervals. It must be regarded as in some degree accidental that the composite line formed by the numerous arcs should eventually form a closed area. In fact, in the majority of cases, the line did not so close upon itself. In

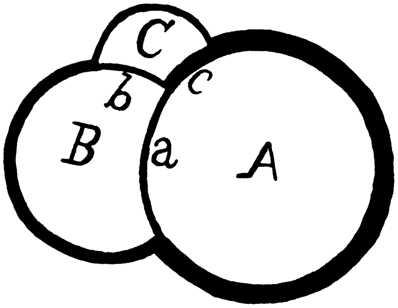

FIG. 8.—Diagrammatic cross-section of a three-chambered concretion.

such cases the concretion is not a closed tube, but is a more or less corrugated sheet, the corrugations, however, having the usual orientation. Such a corrugated sheet may be observed in the upper part of Fig. 4.

The formation of the secondary chambers of the compound concretions is to be ascribed to the same tendency to change the center of curvature. Ordinarily, new molecules coming in contact with the wall of a concretion simply went to increase the thickness of that wall, but not always. At any time some innovating molecule was likely to align itself so as to form a starting-point for a new arched surface, which would compel additional molecules to arrange themselves in conformity to its general scheme, until succeeding arches cut it off from further growth.